THE UNIVERSITY *of* EDINBURGH
informatics

Extreme Computing

BitTorrent and incentive-based overlay networks

BitTorrent

- Today we will focus on BitTorrent

- The technology really has three aspects
  - A standard that BitTorrent client systems follow
  - Some existing clients, e.g., the free Torrent client, PPLive
  - A clever idea: using “tit-for-tat” (incentive) mechanisms to reward good behavior and to punish bad behavior

- This third aspect is especially intriguing

Why is (studying) BitTorrent important?

- An organic, large-scale P2P network
  - That scales according to use
  - Incentive-based: the more you give, the more you get
- Used as a delivery method for multiple media
  - Not only illegally obtained copyrighted material
  - Linux iso's delivery
  - (Legal) Media content distribution

- November 2004: BitTorrent responsible for 35% of all Internet traffic.
- February 2009: P2P networks account for approximately 43% to 70% of all Internet traffic (depending on geographical location)
- January 2012: 150 million active users
  - Monthly users projected to 1 billion
- February 2013: BitTorrent responsible for 3.35% of all worldwide bandwidth
  - More than half of the 6% of total bandwidth dedicated to file sharing

The basic BitTorrent scenario

- Millions want to download the same popular huge files (for free)
  - ISO’s
  - Media (the real example!)
    - And the one that gave BitTorrent a bad rep
- Client-server model fails
  - Single server fails
  - Cannot afford to deploy enough servers
- Why not IP multicast?
  - Not a real option in general WAN settings
    - Not supported by many ISPs
  - Most commonly seen in private data centers
- Alternatives
  - End-host based Multicast
  - BitTorrent
  - Other P2P file-sharing schemes (from prior lectures)

Why not use IP Multicast?

- IP Multicast not a real option in general WAN settings
  - Not supported by many ISPs
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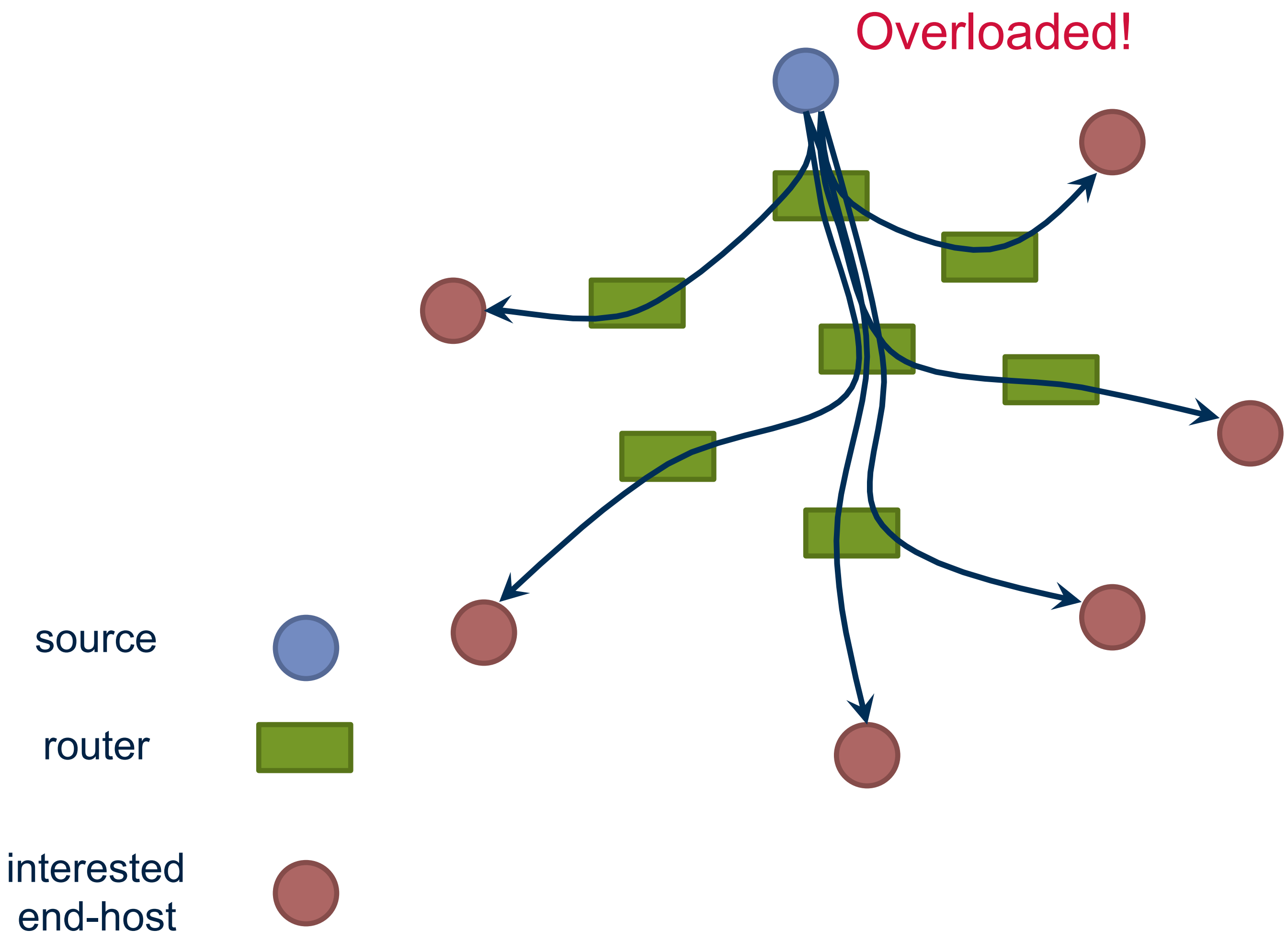
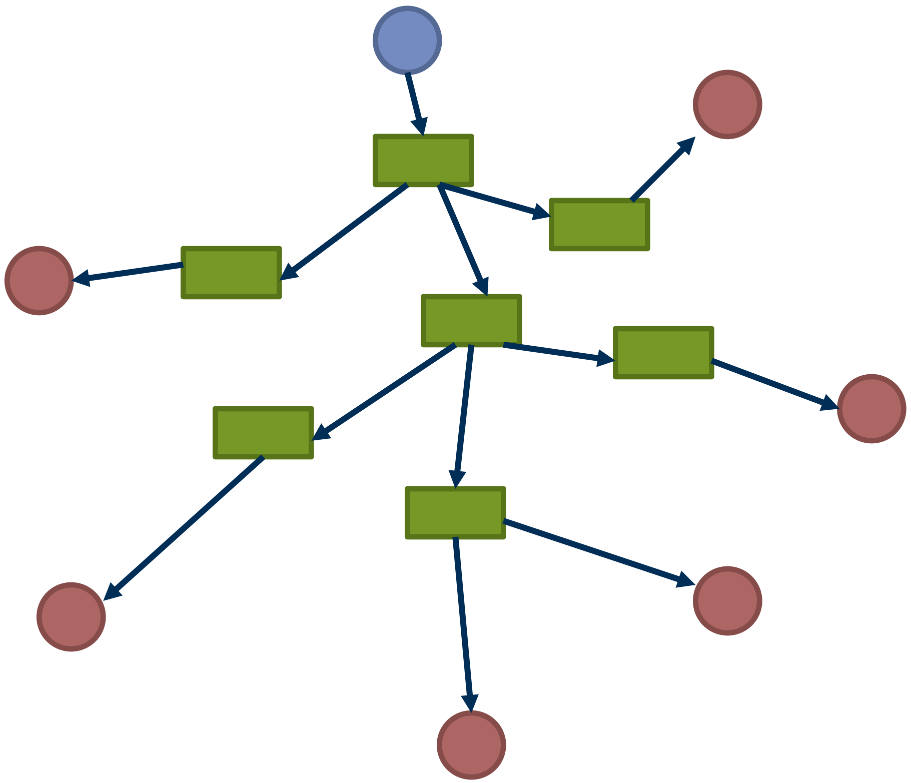
- Alternatives
  - End-host based Multicast
  - BitTorrent
  - Other P2P file-sharing schemes (from prior lectures)

Traditional client-server



IP multicast

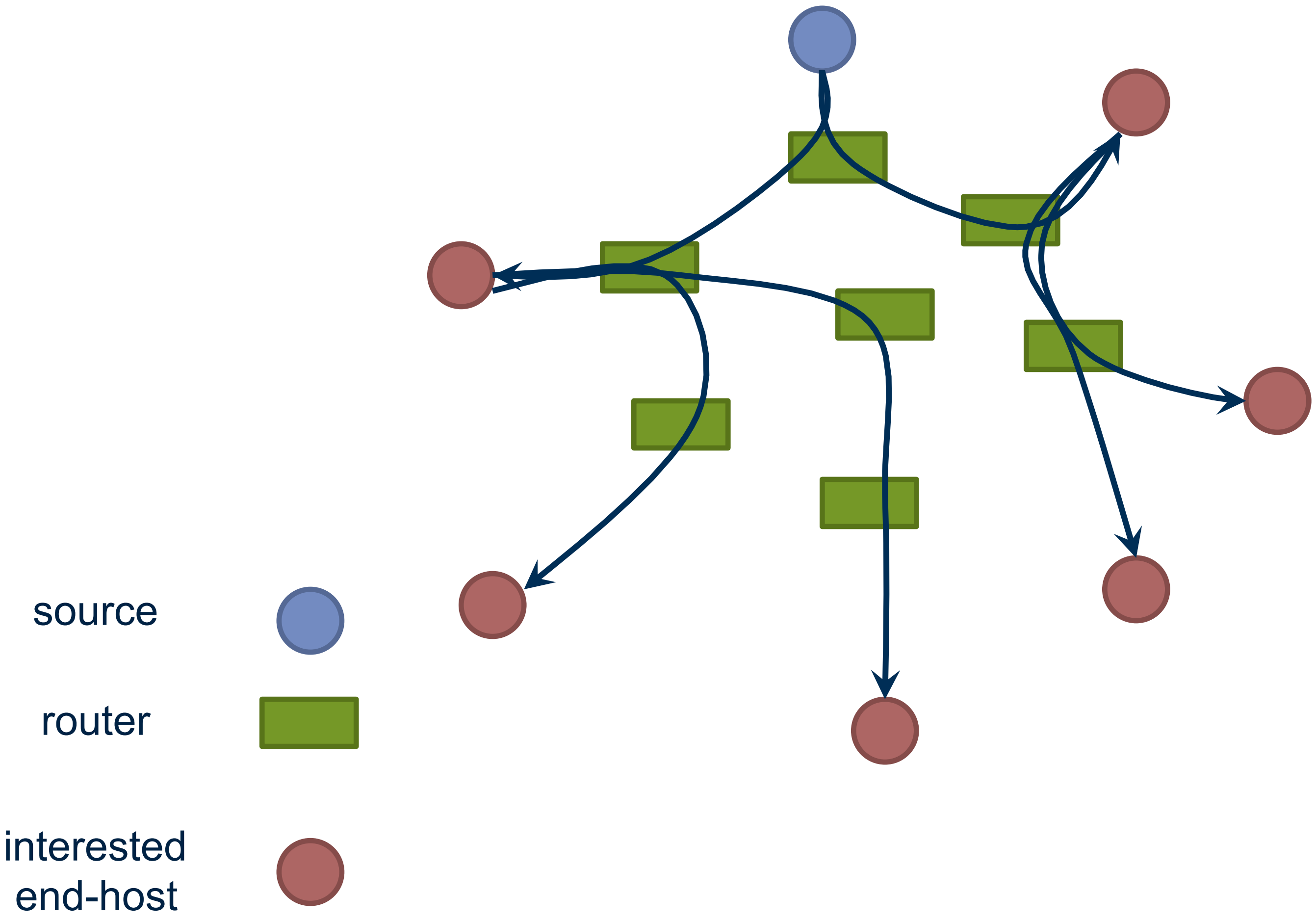


source 🔵

router 🟩

interested end-host 🔴

End-host based multicast



source

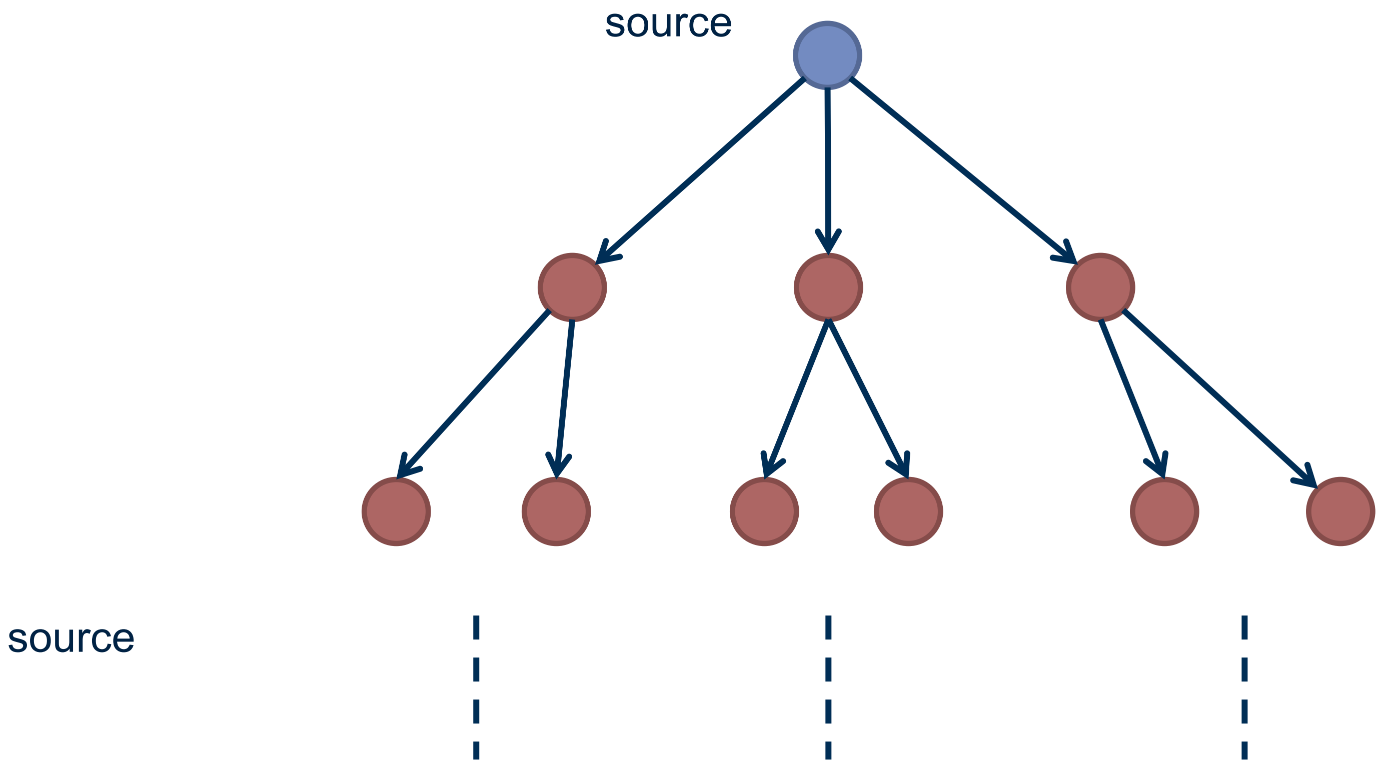
router

interested end-host

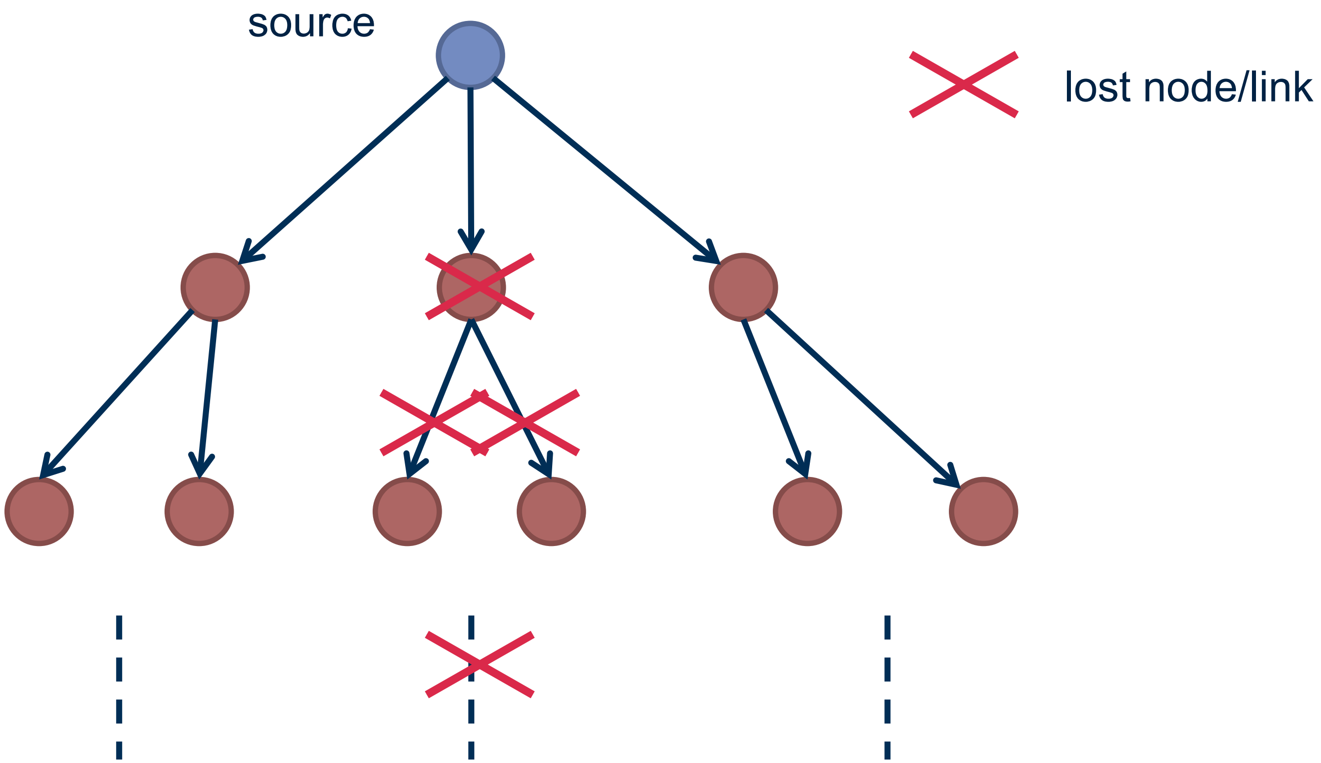
End-host based multicast

- Single uploader → Multiple uploaders
  - Lots of nodes want to download
  - Make use of their uploading abilities as well
  - Node that has downloaded (part of) file will then upload it to other nodes.
- Uploading costs amortised across all nodes
- Also called “Application-level Multicast”
- Many protocols proposed early in the last decade
  - Yoid (2000), Narada (2000), Overcast (2000), ALMI (2001)
    - All use single trees
    - Problem with single trees?

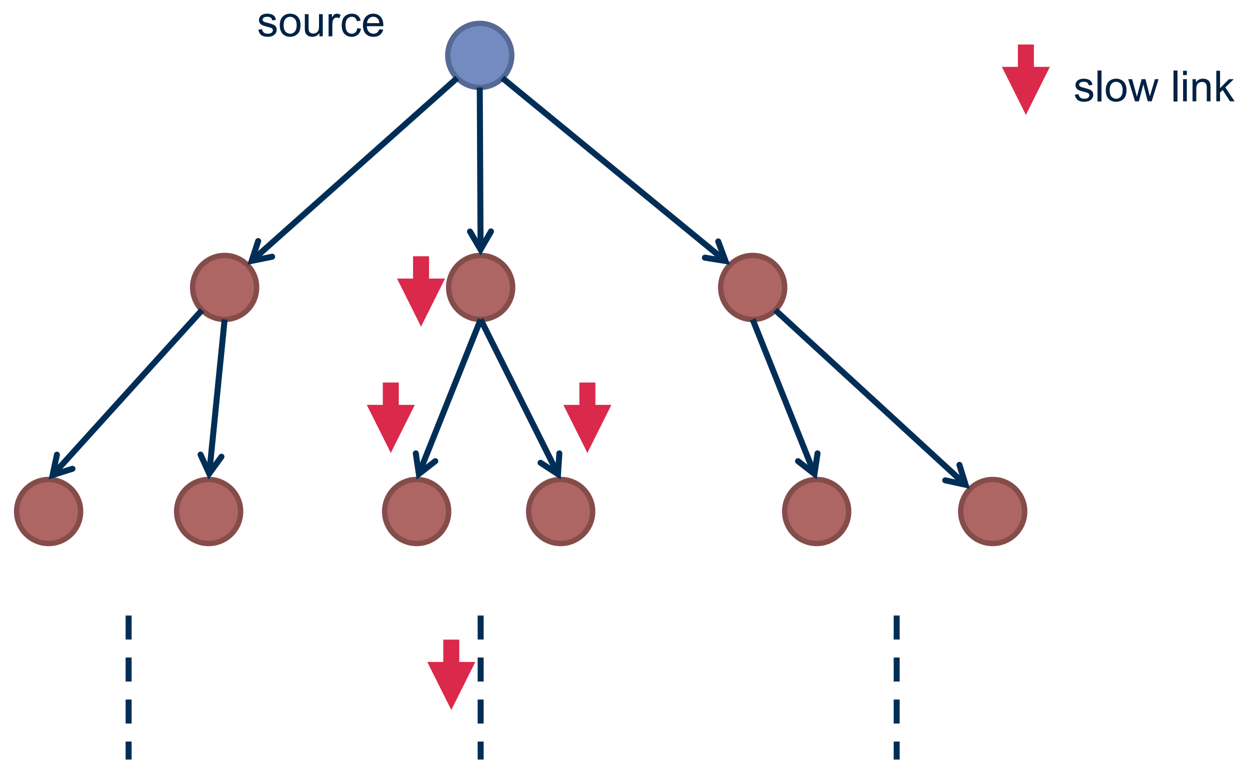
End-host multicast using single tree



End-host multicast using single tree



End-host multicast using single tree



End-host multicast using single tree

- Tree is push-based
  - Node receives data, pushes data to children
  - Failure of interior node affects downloads in entire subtree rooted at node
  - Slow interior node similarly affects entire subtree
- Also, leaf-nodes don’t do any sending

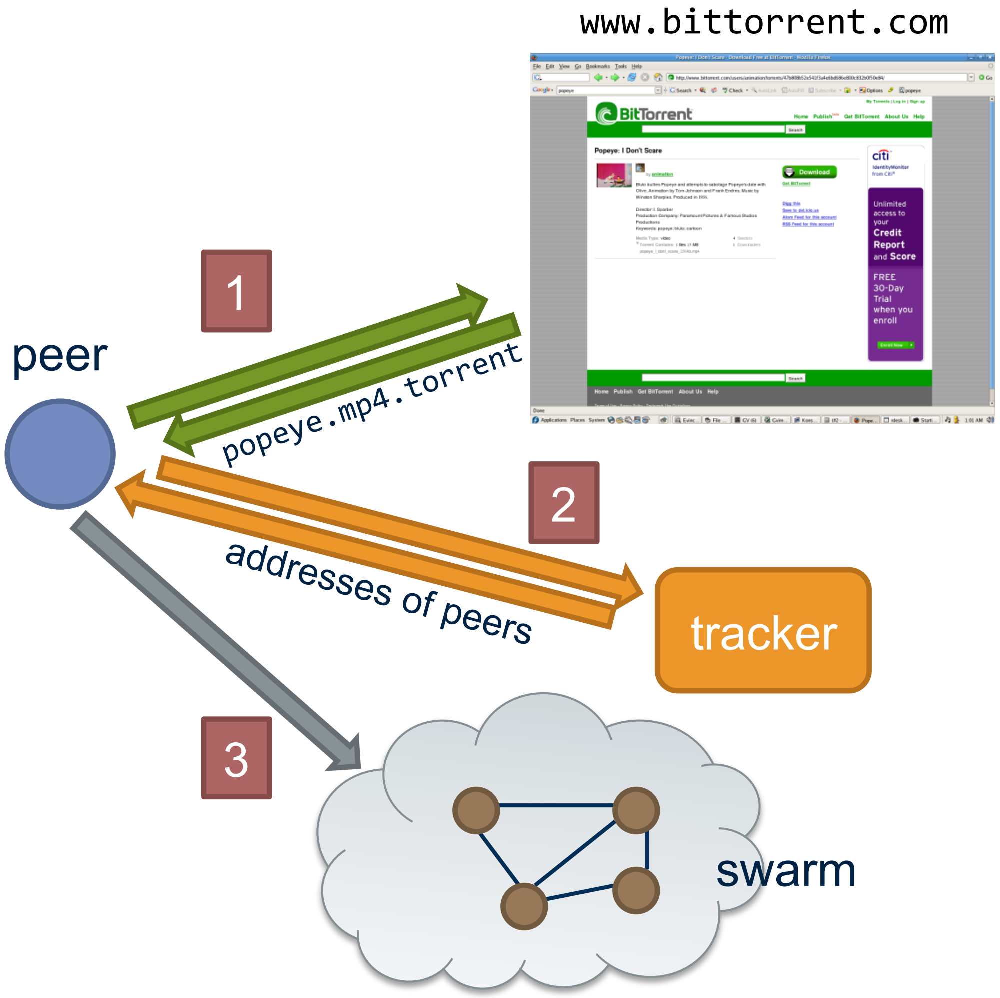
BitTorrent

- Written by Bram Cohen (in Python) in 2001
- Pull-based “swarming” approach
  - Each file split into smaller pieces
  - Nodes request desired pieces from neighbors
    - As opposed to parents pushing data that they receive
  - Pieces not downloaded in sequential order
  - Previous multicast schemes aimed to support streaming; BitTorrent does not
- Encourages contribution by all nodes

BitTorrent swarm

- Swarm
  - Set of peers all downloading the same file
  - Organized as a random mesh
- Each node knows list of pieces downloaded by neighbors
- Node requests pieces it does not own from neighbors
  - Exact method explained later

Entering a swarm for file `popeye.mp4`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http://www.bittorrent.com/users/animation/torrents/47b808b52e541f3a4e6bd686e800c832b0f50e84/

Popeye: I Don't Scare

by animation

Bluto bullies Popeye and attempts to sabotage Popeye's date with Olive. Animation by Tom Johnson and Frank Endres. Music by Winston Sharples. Produced in 1936.

Director: I. Sparber
Production Company: Paramount Pictures & Famous Studios Productions
Keywords: popeye; bluto; cartoon

Media Type: video
Torrent Contains: 1 files 13 MB
popeye_i_dont_scare_256kb.mp4

- File `popeye.mp4.torrent` hosted at a (well-known) webserver
- The .torrent has address of tracker for file
- The tracker, which runs on a webserver as well, keeps track of all peers downloading file

Contents of `.torrent` file and terminology

- URL of tracker
- Piece length – Usually 256 KB
- SHA-1 hashes of each piece in file
  - For reliability
- Files: allows download of multiple files
- Terminology
  - Seed: peer with the entire file
    - Original Seed: The first seed
  - Leech: peer that's downloading the file
    - Fairer term might have been downloader
  - Sub-piece: Further subdivision of a piece
    - The unit for requests is a sub-piece
    - But a peer uploads only after assembling complete piece

Peer-peer transactions: choosing pieces to request

- Rarest-first:
  - Look at all pieces at all peers, and request piece that's owned by fewest peers
  - Increases diversity in the pieces downloaded
    - Avoids case where a node and each of its peers have exactly the same pieces; increases throughput
  - Increases likelihood all pieces still available even if original seed leaves before any one node has downloaded entire file

- Random First Piece:
  - When peer starts to download, request random piece.
    - So as to assemble first complete piece quickly
    - Then participate in uploads
  - When first complete piece assembled, switch to rarest-first

- End-game mode:
  - When requests sent for all sub-pieces, (re)send requests to all peers.
  - To speed up completion of download
  - Cancel request for downloaded sub-pieces

Tit-for-tat: incentive to upload

- Want to encourage all peers to contribute
- Peer *A* said to choke peer *B* if it (*A*) decides not to upload to *B*
- Each peer (say *A*) unchokes at most 4 interested peers at any time
  - The three with the largest upload rates to *A*
    - Where the tit-for-tat comes in
  - Another randomly chosen (optimistic unchoke)
    - To periodically look for better choices
- A peer is said to be snubbed if each of its peers chokes it
- To handle this, snubbed peer stops uploading to its peers
- Optimistic unchoking done more often
  - Hope that we will discover a new peer that will upload to us

Why BitTorrent took off

- Better performance through pull-based transfer
  - Slow nodes do not bog down other nodes
- Allows uploading from hosts that have downloaded parts of a file
  - In common with other end-host based multicast schemes
- Practical Reasons (perhaps more important!)
  - Working implementation (Bram Cohen) with simple well-defined interfaces for plugging in new content
  - Many recent competitors got sued / shut down
    - Napster, Kazaa
  - Does not do search
    - Users use well-known, trusted sources to locate content
    - Avoids the pollution problem, where garbage is passed off as authentic content

Pros and cons of BitTorrent

- Proficient in utilizing partially downloaded files
- Discourages “freeloading”
  - By rewarding fastest uploaders
- Encourages diversity through “rarest-first”
  - Extends lifetime of swarm
- Works well for popular content

✓

- Assumes all interested peers active at same time; performance deteriorates if swarm “cools off”
- Even worse: no trackers for obscure content

✗

- Dependence on centralized tracker: pro/con?
  - Single point of failure ✗
    - New nodes can’t enter swarm if tracker goes down
  - Lack of a search feature
    - Prevents pollution attacks ✓
    - Users need to resort to out-of-band search: well known torrent-hosting sites / plain old web-search ✗

“Trackerless” BitTorrent

- To be more precise, “BitTorrent without a centralized-tracker”
- E.g.: Azureus
- Uses a Distributed Hash Table (Kademlia DHT)
- Tracker run by a normal end-host (not a web-server anymore)
  - The original seeder could itself be the tracker
  - Or have a node in the DHT randomly picked to act as the tracker

Summary

- Described a large-scale file sharing system
  - BitTorrent
  - Out-of-the-box thinking
- Discussed the salient features of the system
- Described the pros and cons of its design decisions
- The right tool for the job
  - Sometimes, going “extreme” does not require extremely complicated infrastructure
  - But extremely well-executed targeted solutions